makes it isovalent with In and hence doping is not expected to lead to the introduction of charge carriers. Moreover, its size is comparable to that of the In, allowing for substitutional doping without significant lattice distortions. These features of Au are consistent with the absence of significant shifts in absorption, emission and Fermi energy, as observed in both optical and tunneling spectra.

EXPERIMENTAL

Materials

In(III)Cl_3 (99.999+%), tris(trimethylsilyl) arsenide (TMS3As), trioctylphosphine (TOP, 90%; purified by vacuum distillation and kept in the glovebox), $AuCl_3$ (99%), AgCl (99+%), $AgNO_3$ (99+%), $CuCl_2$ (99.999%), dodecylamine (DDA, 98%), didodecyldimethylammonium bromide (DDAB, 98%), toluene (99.8% anhydrous), methanol (99.8% anhydrous) were purchased from Sigma Aldrich except for (TMS_3As) which was synthesized as detailed in the literature [17].

Methods

InAs Nanocrystal Synthesis

The synthesis of InAs nanocrystals (NCs) was carried out under an inert atmosphere using standard Schlenck techniques.

In a typical synthesis a mixture of indium and arsenic precursors were prepared by adding 0.3 g (1 mmol) of (TMS_3As) to 1.7 g of a 1.4M $InCl_3$ TOP solution (2 mmol in total). 1 ml of this solution was injected into a three neck-flask containing 2 ml of TOP at 300° C. under vigorous stirring. The temperature was then reduced to 260° C. and further precursor solution was added in order to achieve particle growth. The growth was monitored by taking the absorption spectra of aliquots extracted from the reaction solution. Upon reaching the desired size, the reaction mixture was allowed to cool to room temperature and was transferred into a glovebox. Anhydrous toluene was added to the reaction solution, and the nanocrystals were precipitated by adding anhydrous methanol. The size distribution of the nanocrystals in a typical reaction was on the order of 10%. This was improved using size selective precipitation with toluene and methanol as the solvent and anti-solvent, respectively.

Metal-Atom Doping

In a typical reaction a metal solution was prepared by dissolving 10 mg of the metal salt ($CuCl_2$, $AgNO_3$, AgCl or $AuCl_3$), 80 mg DDAB and 120 mg of DDA in 10 ml of toluene. The Cu and Ag solutions prepared in this manner are respectively blue, colorless and yellow. The metal solution was then added drop-wise to a stirred 2 ml toluene solution of InAs NCs. After 15 minutes the absorption and emission of the solutions were measured. The Cu and Au samples were precipitated with methanol whilst the Ag sample was precipitated with acetone. The entire metal treatment procedure was carried out under inert conditions. The ratio of metal atoms to NCs in solution was estimated from the literature values of InAs NC absorption cross-sections.

The invention claimed is:

1. A nanoparticle comprising

a semiconductor material, the semiconductor material being doped with at least two atoms of a dopant material, wherein

the at least two atoms of the dopant material are heterovalent to atoms of the semiconductor material, said at least two atoms of the dopant material being dispersed within the semiconductor material, and

the nanoparticle is free of dopant islands within the nanoparticle and free of dopant islands on the surface of the nanoparticle.

2. A nanoparticle according to claim **1**, wherein said at least two atoms of the dopant material alter the density of states of the semiconductor material.

3. The nanoparticle according to claim **1**, wherein the nanoparticle consists of the semiconductor material doped with at least two atoms of the dopant material.

4. The nanoparticle according to claim **1**, wherein an average length or diameter of the nanoparticle is in the range of 1 nm to 500 nm.

5. The nanoparticle according to claim **1**, wherein the semiconductor material is selected from the group of elements consisting of Group I-VII, Group II-VI, Group III-V, Group IV-VI, Group III-VI, and Group IV semiconductors and combinations thereof.

6. The nanoparticle according to claim **5**, wherein the semiconductor material is a Group I-VII material being selected from the group consisting of CuCl, CuBr, CuI, AgCl, AgBr, and AgI, or the semiconductor material is a Group II-VI material selected from the group consisting of CdSe, CdS, CdTe, ZnSe, ZnS, ZnTe, HgS, HgSe, HgTe, CdZnSe, ZnO and any combination thereof, or the semiconductor is a Group III-V material being selected from the group consisting of InAs, InP, InN, GaN, InSb, InAsP, InGaAs, GaAs, GaP, GaSb, AlP, AlN, AlAs, AlSb, CdSeTe, ZnCdSe and any combination thereof, or the semiconductor material is a Group IV-VI material being selected from the group consisting of PbSe, PbTe, PbS, PbSnTe, Tl_2SnTe_5 and any combination thereof, or the semiconductor material comprises an element of Group IV being selected from the group consisting of Si and Ge.

7. The nanoparticle according to claim **5**, wherein the semiconductor material is selected from CdSe, CdS, CdTe, ZnSe, ZnS, ZnTe, HgS, HgSe, HgTe, CdZnSe, InAs, InP, InN, GaN, InSb, InAsP, InGaAs, GaAs, GaP, GaSb, AlP, AlN, AlAs, AlSb, CdSeTe, ZnCdSe, PbSe, PbTe, PbS, PbSnTe, Tl_2SnTe_5, RuS_2, RuO_2, MoS_2, MoO_3, RhS_2, RuO_4, WS_2, WO_2, Cu_2S, Cu_2Se, Cu_2Te, $CuInS_2$, $CuInSe_2$, $CuInTe_2$ and any combination thereof.

8. The nanoparticle according to claim **7**, wherein the semiconductor material is selected from InAs, InP, InN, GaN, InSb, InAsP, InGaAs, GaAs, GaP, GaSb, AlP, AlN, AlAs, AlSb, CdSeTe, ZnCdSe and any combination thereof.

9. The nanoparticle according to claim **8**, wherein the semiconductor material is selected from InAs, GaAs, GaP, GaSb, InP, InSb, AlAs, AlP, AlSb and InGaAs.

10. The nanoparticle according to claim **9**, wherein the semiconductor material is InAs.

11. The nanoparticle according to claim **1**, wherein the dopant material is selected from the group consisting of materials which atoms differ from atoms composing the semiconductor material by one or more valance electron(s).

12. The nanoparticle according to claim **11**, wherein the dopant material is selected amongst metals and non-metal materials, said dopant being Li or Mg or Na or K or Rb or Cs or Be or Ca or Sr or Ba or Sc or Ti or V or Cr or Fe or Ni or Cu or Zn or Y or La or Zr or Nb or Tc or Ru or Mo or Rh or W or Au or Pt or Pd or Ag or Co or Cd or Hf or Ta or Re or Os or Ir or Hg or B or Al or Ga or In or Tl or C or Si or Ge or Sn or Pb or P or As or Sb or Bi or O or S or Se or Te or Po or F or Cl or Br or I or At, or any combination thereof.